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Before an image is stored or transmitted, we have access to the original and the distorted versions. The enhanced codec is compared to the original block by block to determine which blocks have been improved by the enhancement. These blocks are then flagged for post-processing in a way that is compliant with the JPEG standard and adds nothing to the compressed image's bandwidth. The end result is a compressed image that can be decompressed on any standard JPEG decompressor, but that can be enhanced by a sophisticated decompressor.

For the comparison of the original and enhanced images, we have been developing a new vision model that is specifically tailored to the detection of errors that occur within or between two JPEG codec blocks. Previous filter models have been restricted from using a large number of filters due to computational constraints which we avoid by focusing the model on a tiny spatial area of 8x16 pixels. Further, features of human vision that have been included in previous models (color, temporal, stereo etc.) are not needed for this more focused problem. Issues that have not been completely addressed by previous models, such as masking effects, are tractable and the model is more applicable to JPEG compression.

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A tiny vision model

A number of researchers have been developing systems to automatically assess the visual fidelity of distorted images with varying degrees of success. The goal of this research is to develop an improved fidelity metric that is specifically tailored for the detection of errors that occur in a single JPEG codec block, or between two JPEG codec blocks. Previous filter models have been restricted from using a large number of filters due to computational constraints. By focusing the model on a tiny spatial area of 8x8 or 8x16 pixels, it will be possible to have a huge variety of filters without an excessive computational burden. Further, many of the features of human vision that have been included in previous models (color, temporal, stereo etc.) will not be needed for this more focused problem. By limiting the problem, issues that have not been completely addressed by previous models, such as masking effects, will become more tractable. The model will also have more direct applicability to improving JPEG compression, as will be discussed.

Precomputing and encoding enhancement instructions for inclusion with compressed image files

There has been much recent work in the field of image enhancement for digital images. Traditional techniques such as filtering and edge enhancement have been applied to restoring images that have been distorted due to lossy image compression. However, these techniques have ignored a unique feature that can be exploited when working with digital compression. Before the image is stored or transmitted, the sender has access to both the original and the distorted images. Enhancement can be selectively applied and assessed before the image is stored or transmitted, and successful enhancement instructions can be included with the image file.

In this paper we present a technique that can be used to efficiently include a spatial map of enhancement instructions with compressed image files. The method we describe can be used to produce files that are compliant with the JPEG standard, so that the file can be decompressed with a standard decoder. An advanced decoder that can read the enhancement instructions can take the same file and produce an enhanced image.

Before an image is stored or transmitted, we have access to the original and the distorted versions. The enhanced codec is compared to the original block by block to determine which blocks have been improved by the enhancement. These blocks are then flagged for post-processing in a way that is compliant with the JPEG standard and adds nothing to the compressed images' bandwidth. A single JPEG coefficient is adjusted so that the sum of the coefficients contains the flag for post-processing as the parity of the block. Half of the blocks already have the correct parity. In the other blocks, a coefficient that is close to being half way between two values will be chosen and rounded in the other direction. This distorts the image by a very tiny amount. The end result is a compressed image that can be decompressed on any standard JPEG decompressor, but that can be enhanced by a sophisticated decompressor.

In addition to adding single bits of data in the parity of a block, we can use a more complicated parity scheme to add more information. For example, the parity of a block can be adjusted so that the sum of the coefficients modulo 3 is in one of three possible states. The three states can represent three alternate processing schemes, instructions for which of the blocks edges to smooth, or other multi-bit information. We present equations for estimating the error introduced into the image by the parity forcing method, and we compare our estimates to computer simulations and actual image data.

Relative Motion Discrimination

What are the spatial and temporal limits of relative motion discrimination? Motion of very small amplitudes (5 sec or less) can be detected when the frequency of motion is optimal (2-4 Hz). Previous research has shown that under some conditions, the relative motion of two feature can be judged whenever the amplitude of motion is sufficient for detection. In these experiments, we measure the spatial and temporal properties of relative motion discrimination.

We used two sinusoidally oscillating features (dots or lines) to determine the temporal frequency response function of relative motion discrimination. We measured both the threshold amplitude required for detecting and discriminating motion. We also measured the transducer functions that relate amplitude to detectability and discriminibility. We determined the slope of the transducer functions, and found a saturating non linearity for high temporal frequency motion.

The subject was presented with two dots that either oscillated inphase (the dots moved in the same direction) or in counterphase (the dots moved in opposite directions). We varied the temporal frequency of oscillation, the separation between the two features, the lighting conditions, the amplitudes of oscillation and the distance from the fovea of the two features. When the temporal frequency of the presented stimuli is optimal (~4 Hz), the visual system is remarkably adept at discriminating relative motion, if the motion can be detected, its type can be discriminated. Contrary to previous findings, a temporal frequency of more than 8 Hz degrades thresholds relative to detection and at 14 Hz increases them more than 5-fold.